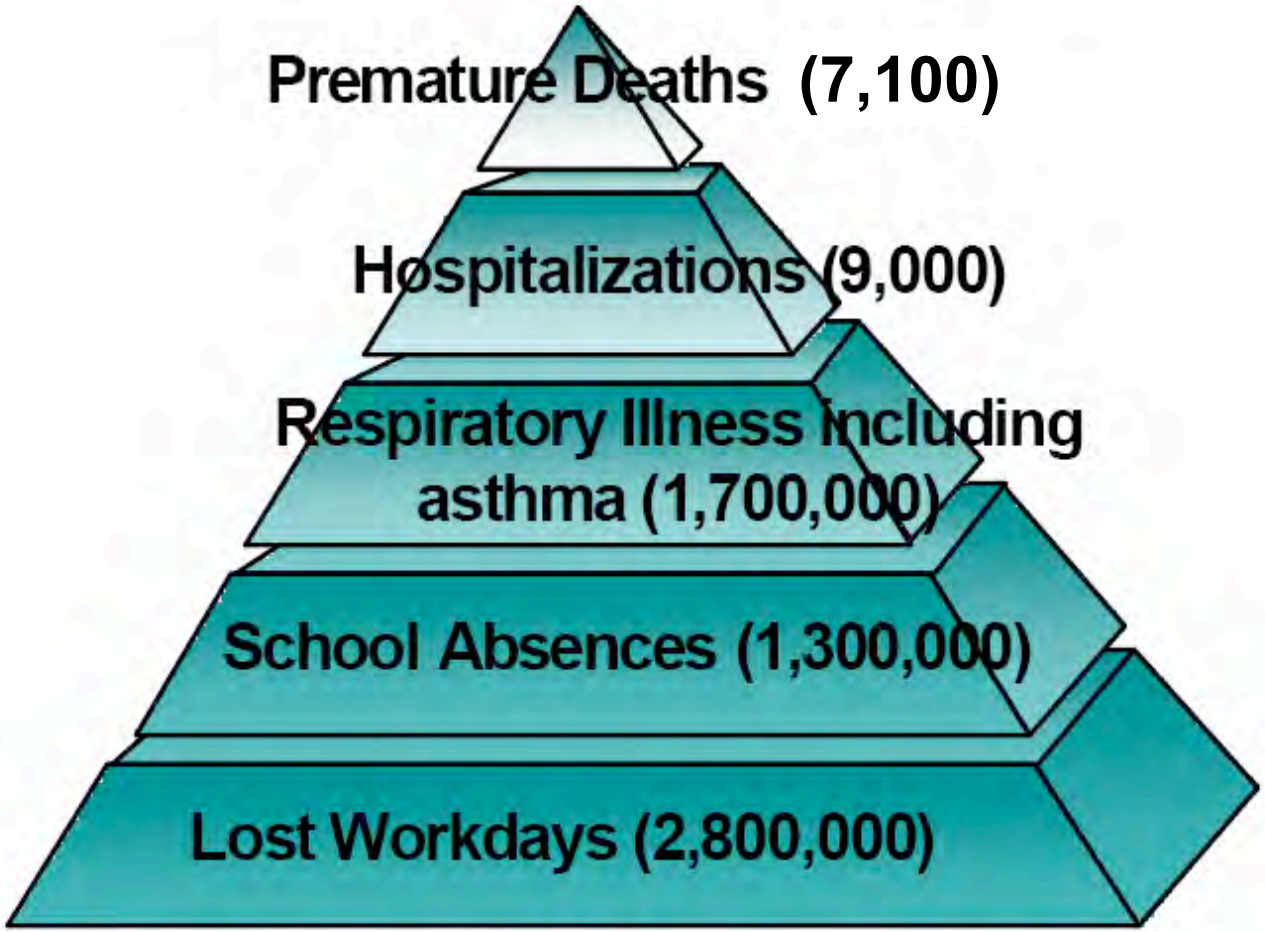
Air Quality and Climate in California

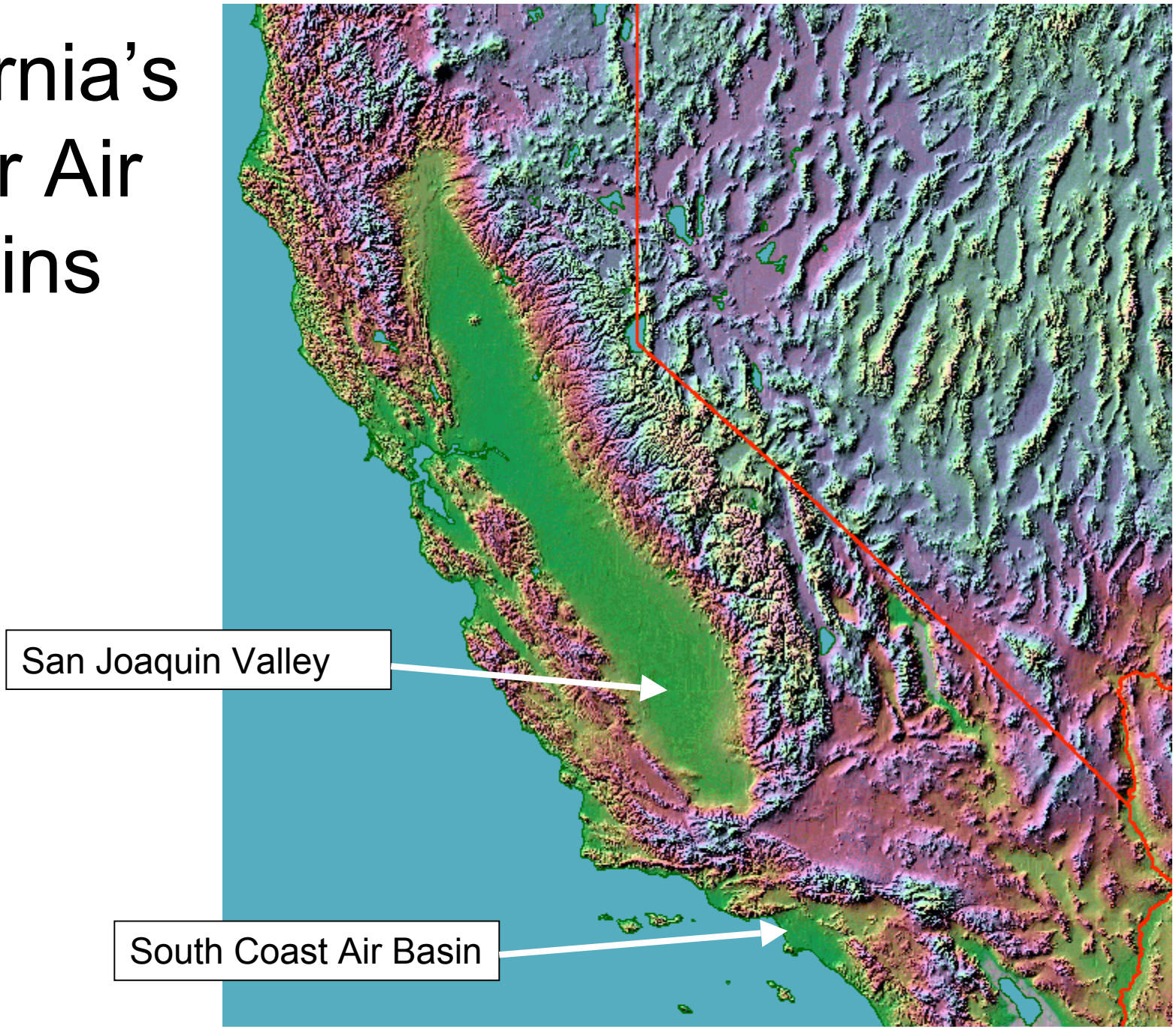
Michael J. Kleeman
Department of Civil and Environmental Engineering
UC Davis

Health Impacts of Air Pollution in California (per year)



Source: Recent Research Findings: Health Effects of Particulate Matter and Ozone Air Pollution, January 2004. California Air Resources Board (http://www.arb.ca.gov/research/health/fs/PM-03fs.pdf)

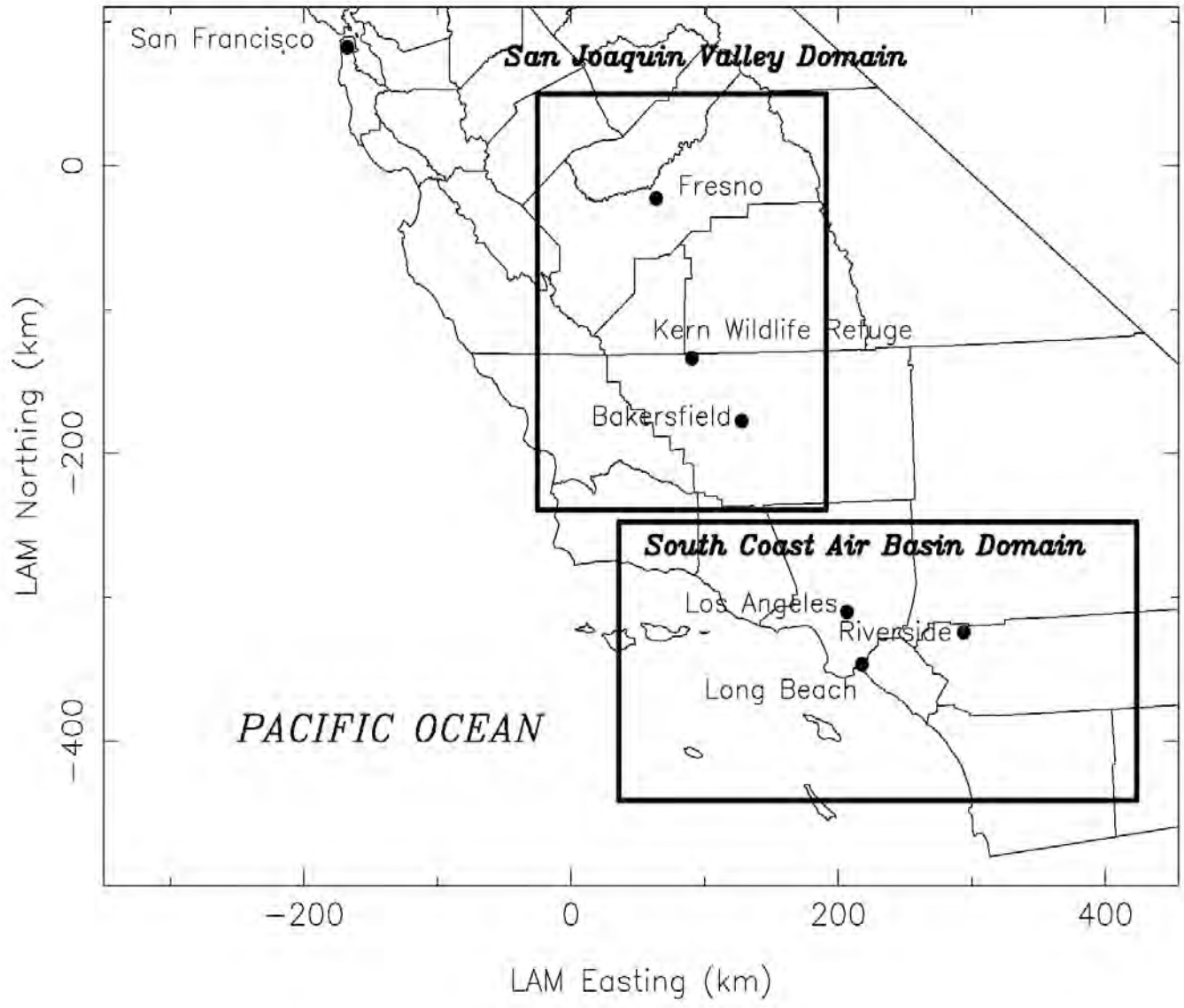
California's Major Air Basins



How Will Climate Change Affect Air Quality?

- Air pollution events occur when meteorology traps emissions close to the surface
- Climate change will affect multiple variables simultaneously
  - Temperature, relative humidity, wind speed, mixing depth, cloud cover, precipitation, etc.

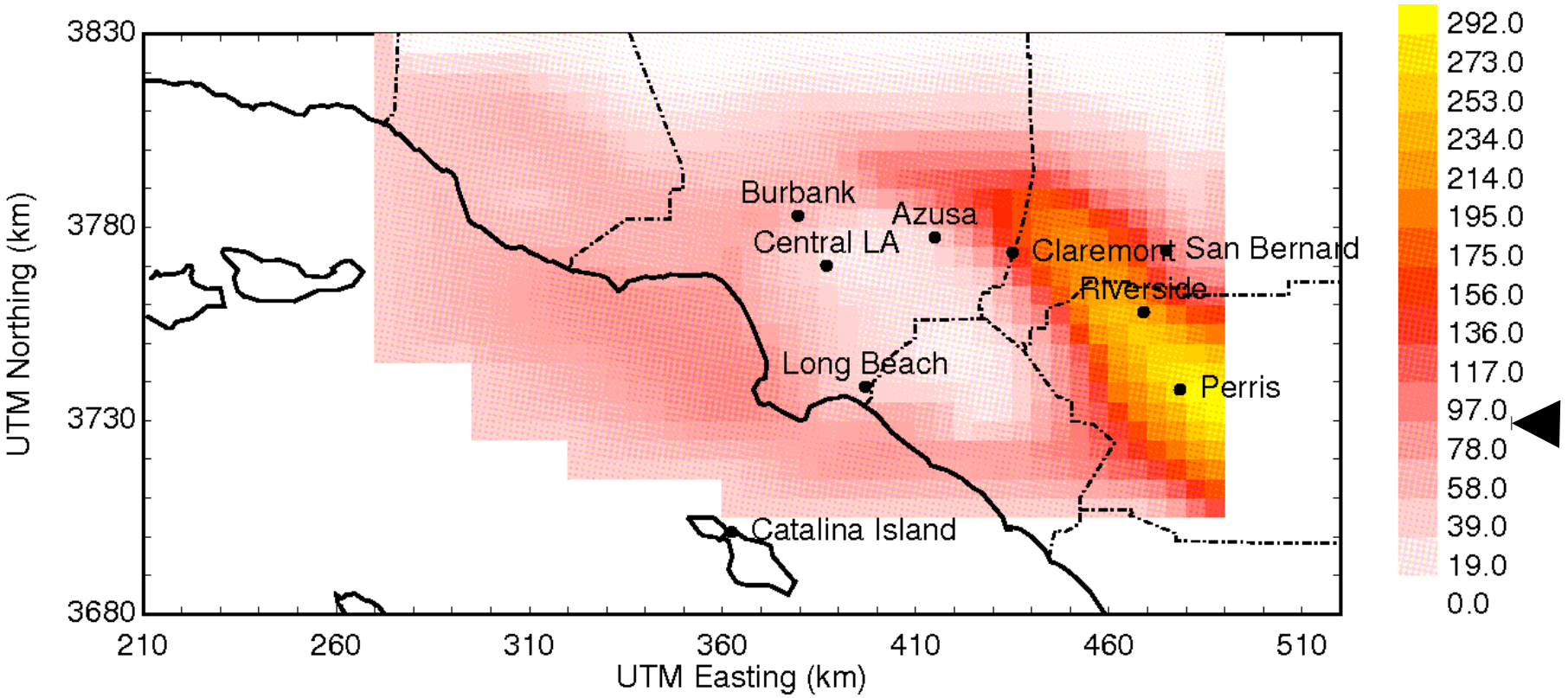
Modeling Domains



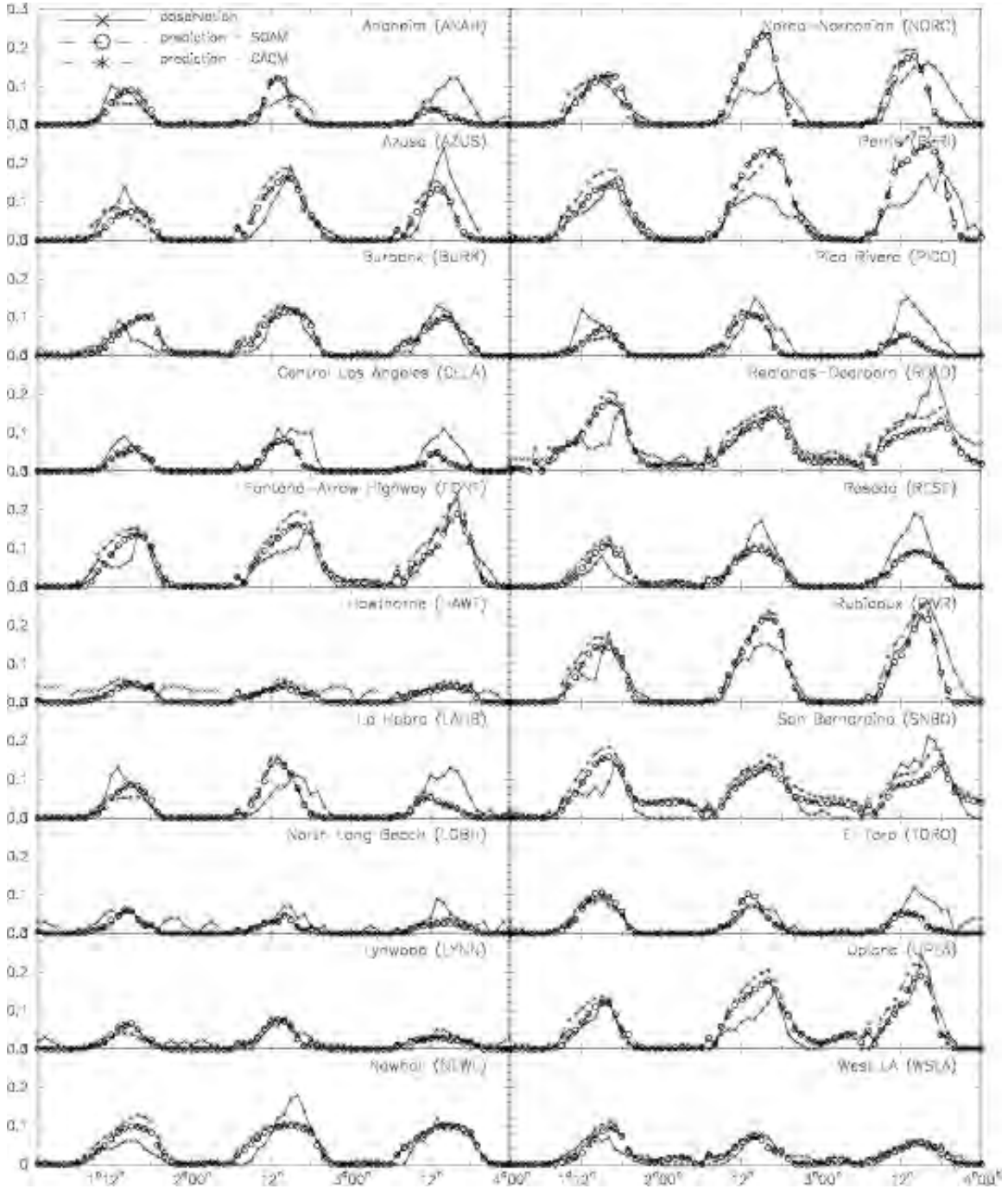
Episode # 1: SoCAB September 7-9, 1993

- Extremely hot episode with inland temperatures greater than 35^{o}C
- Elevated temperature inversion
- Upper winds from the northwest
- Surface winds light from the west during the day, stagnant at night

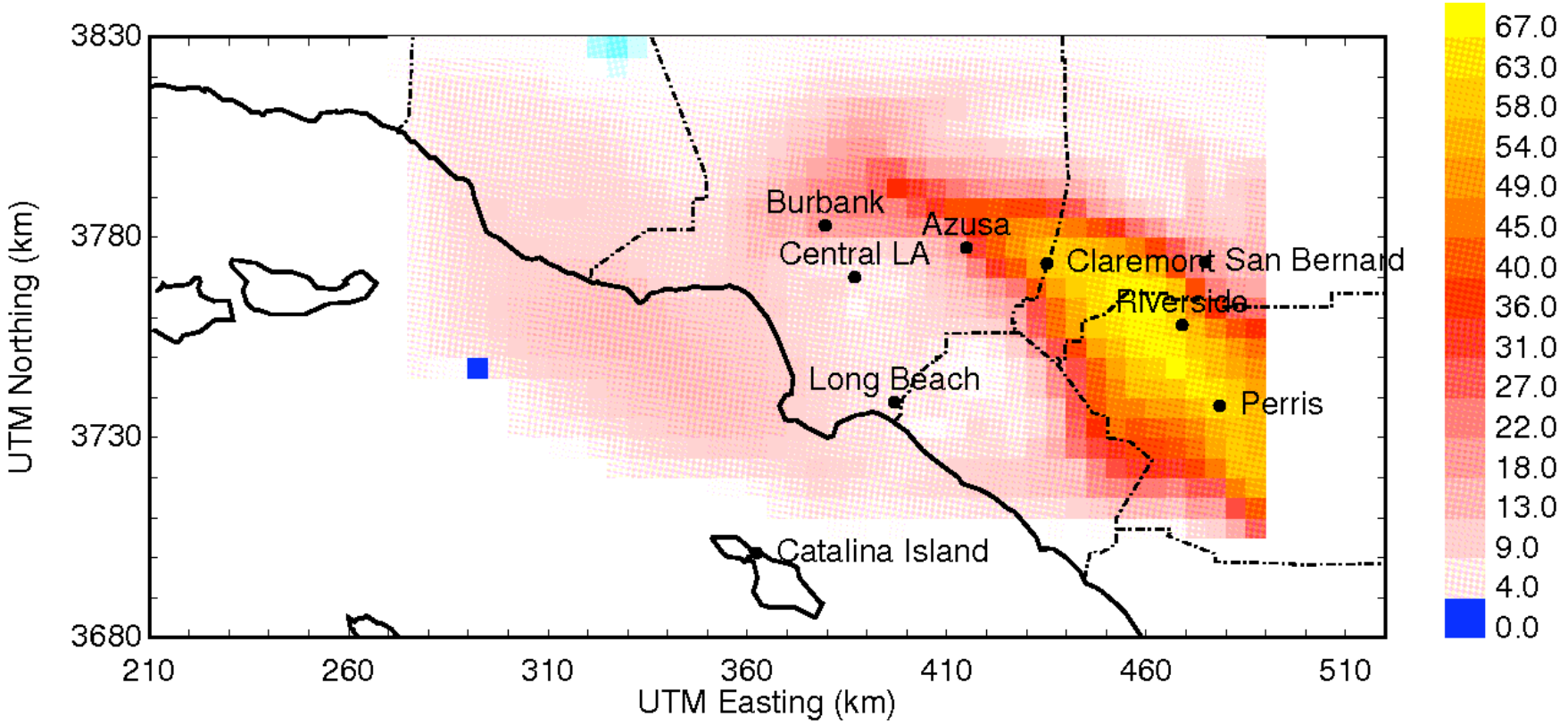
1hr-Average O3 Concentration (ppb) at 1500PST on Sept 9, 1993



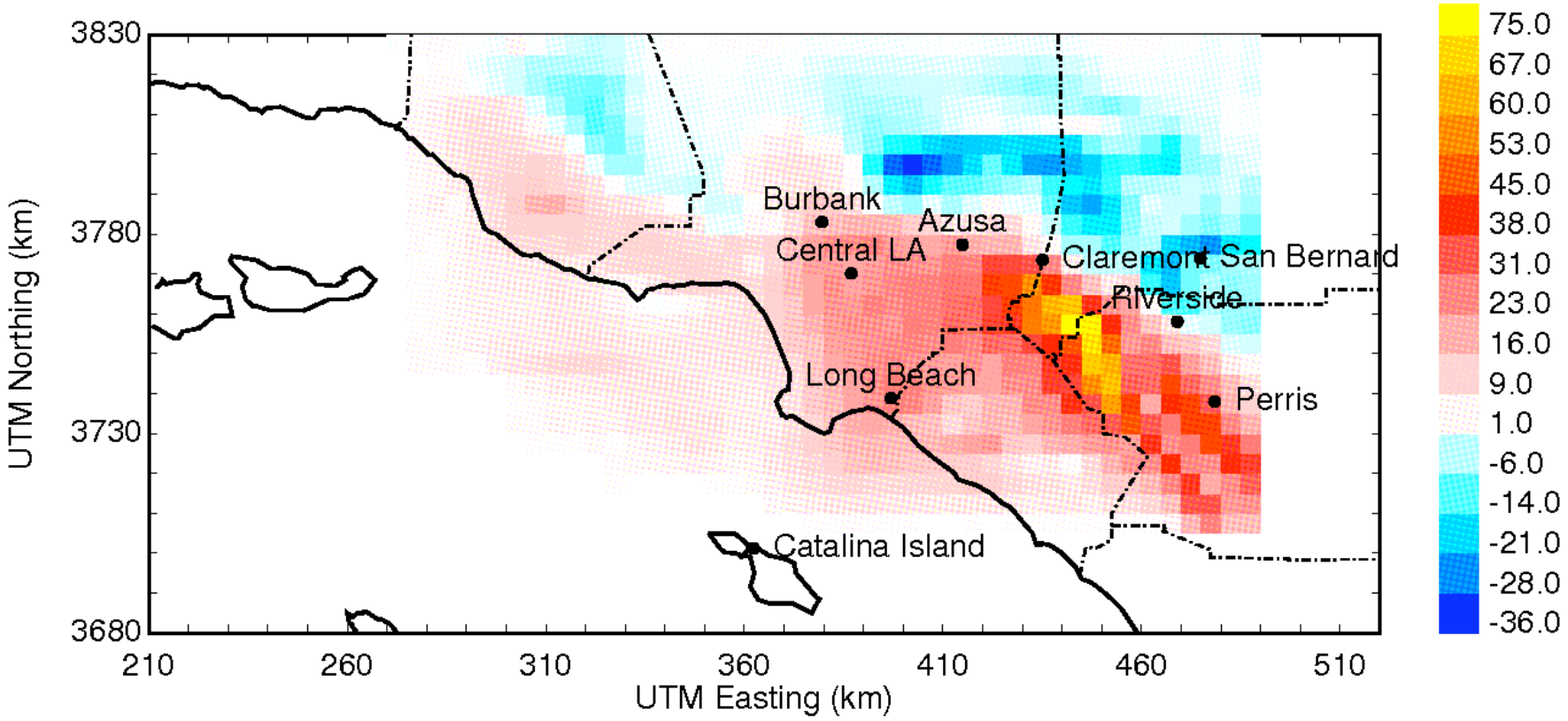
Comparison to Measurements for Ozone:



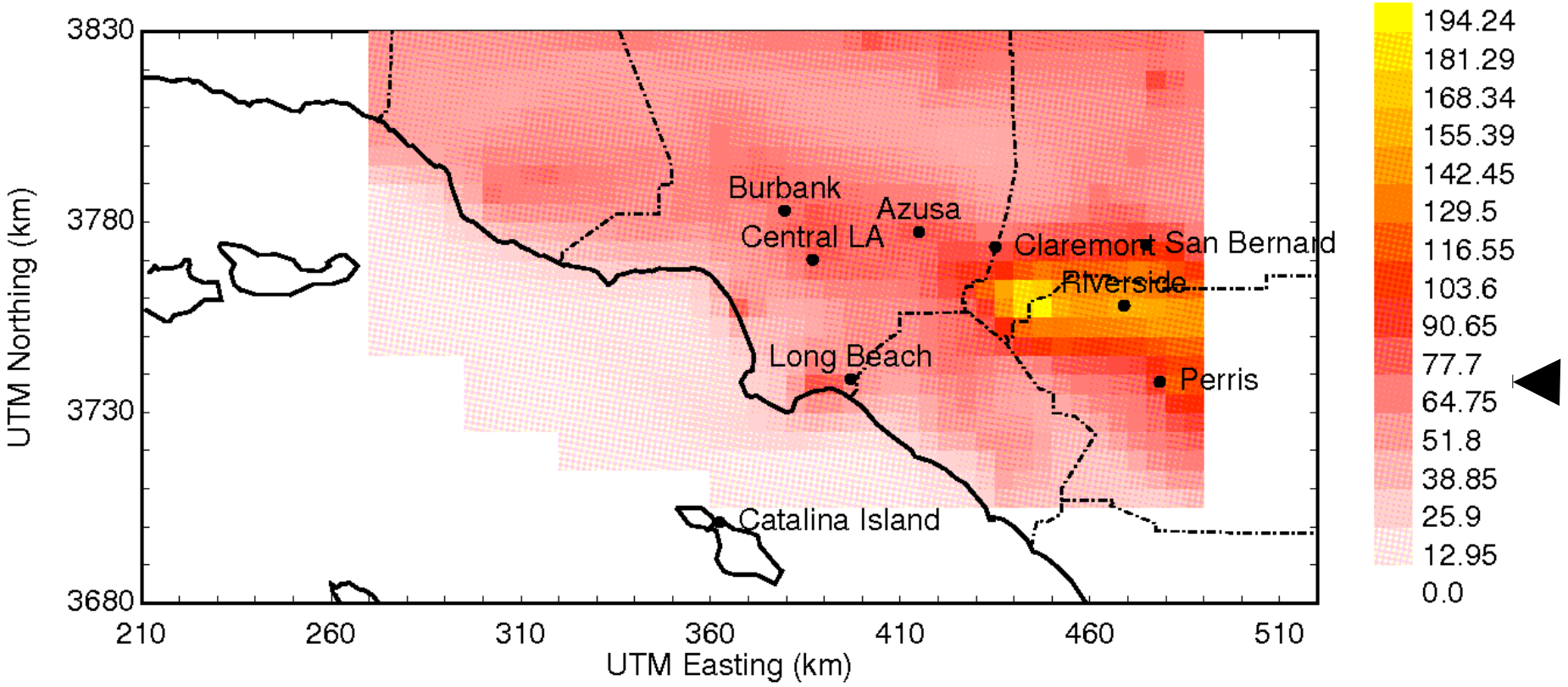
1hr-Average O3 Concentration Difference (ppb) Caused by +5K With Constant RH



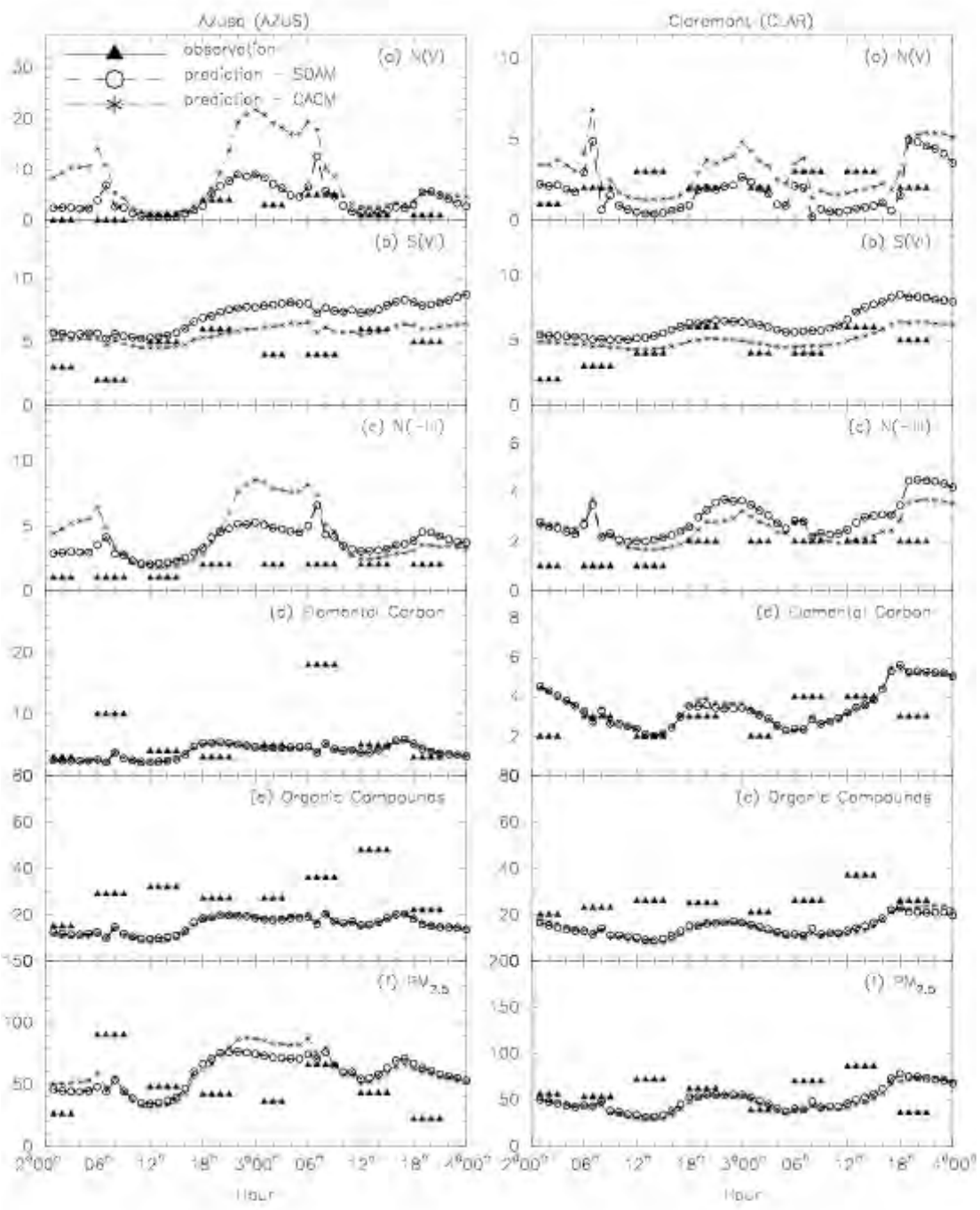
1hr-Average O3 Concentration Difference (ppb) Caused by +50% Increase in Mixing Depth



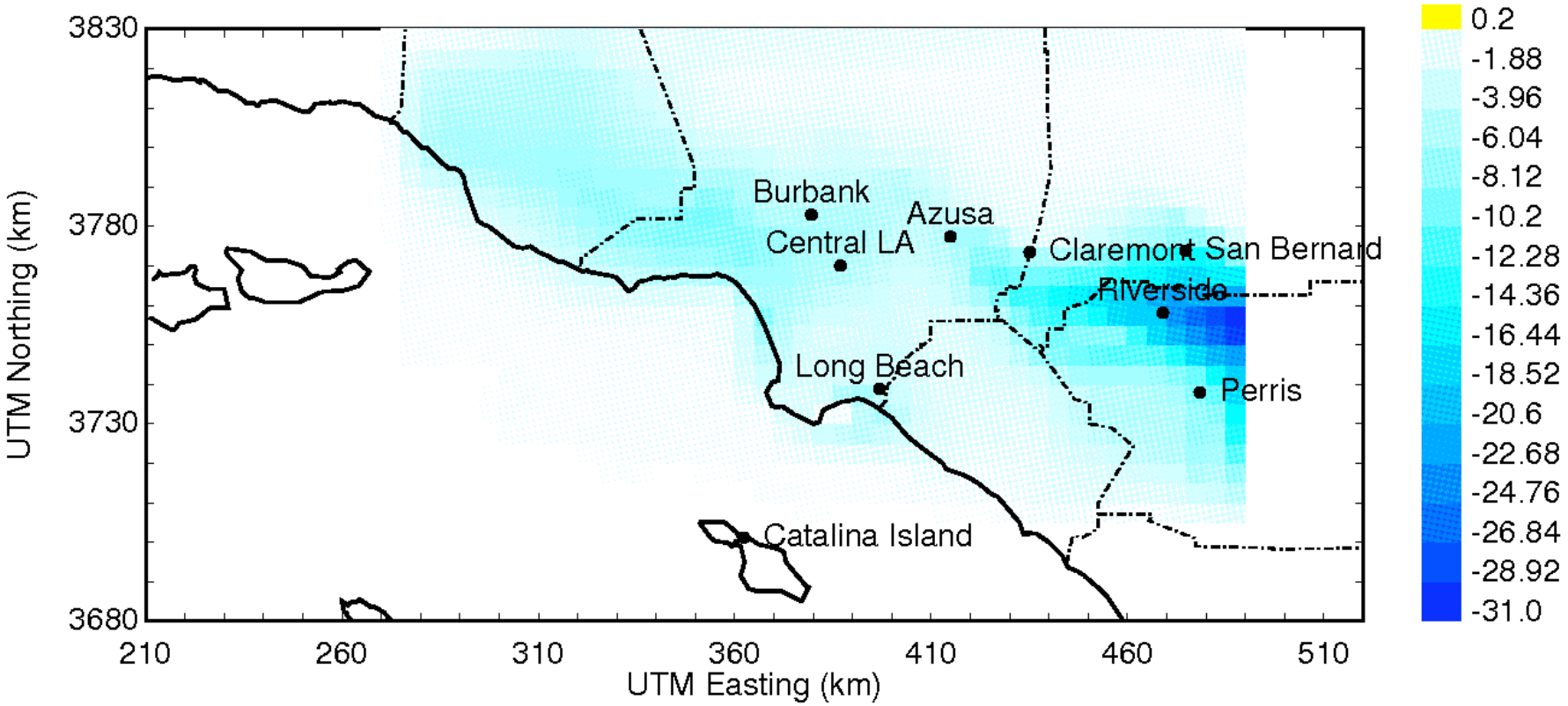
24hr-Average PM2.5 Concentration ($\mu g\ m^{-3}$) on Sept 9, 1993



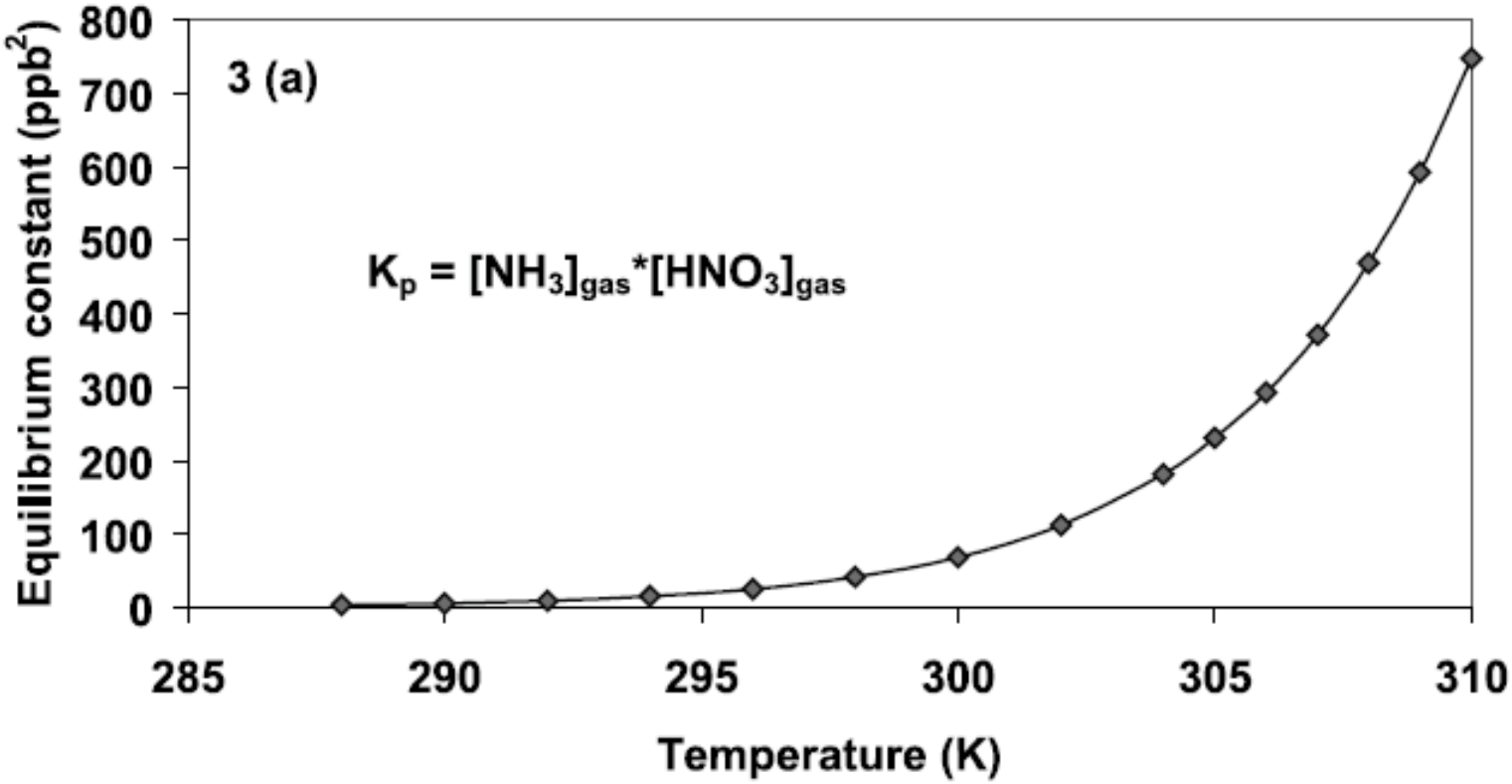
Comparison to Measurements for Particle Mass and Composition:



24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +5K



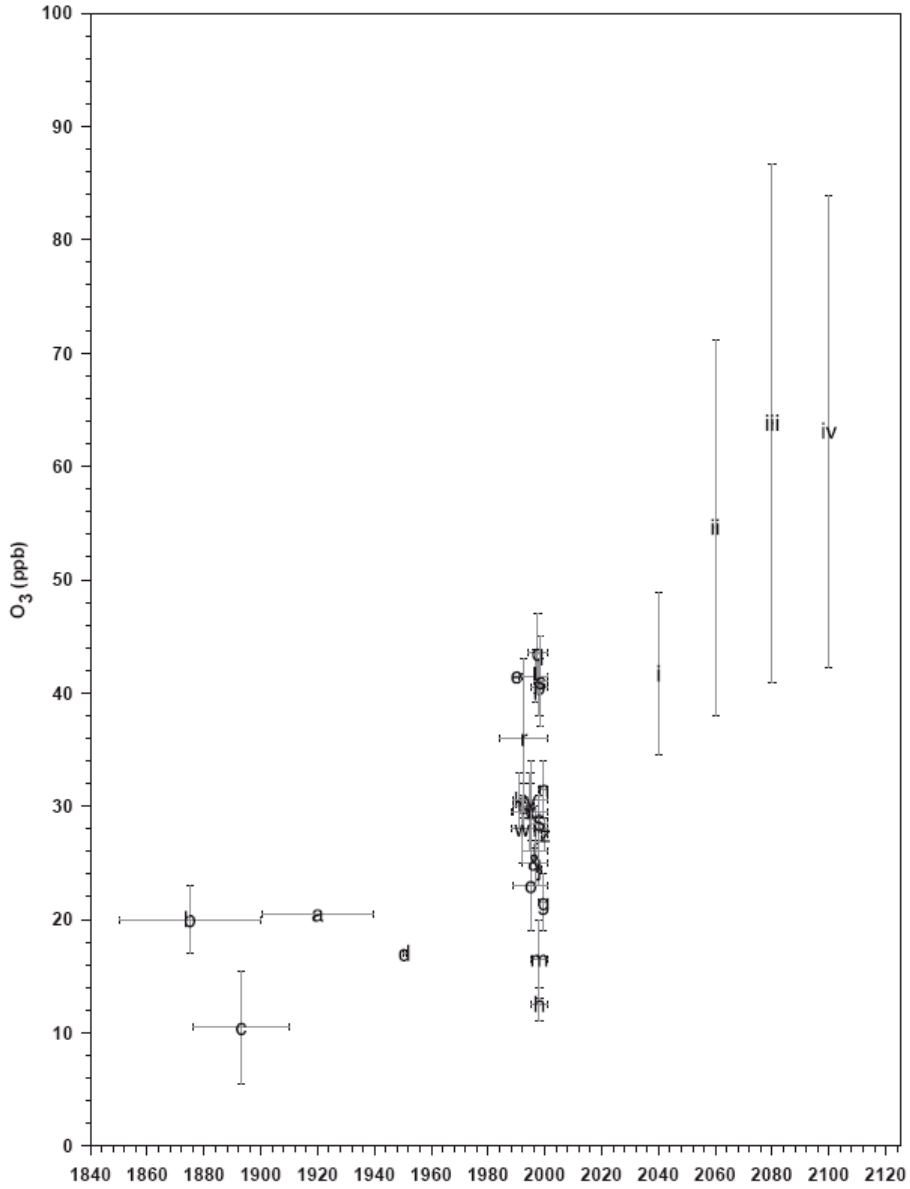
Equilibrium Dissociation Constant for Ammonium Nitrate



Trends for Background O3

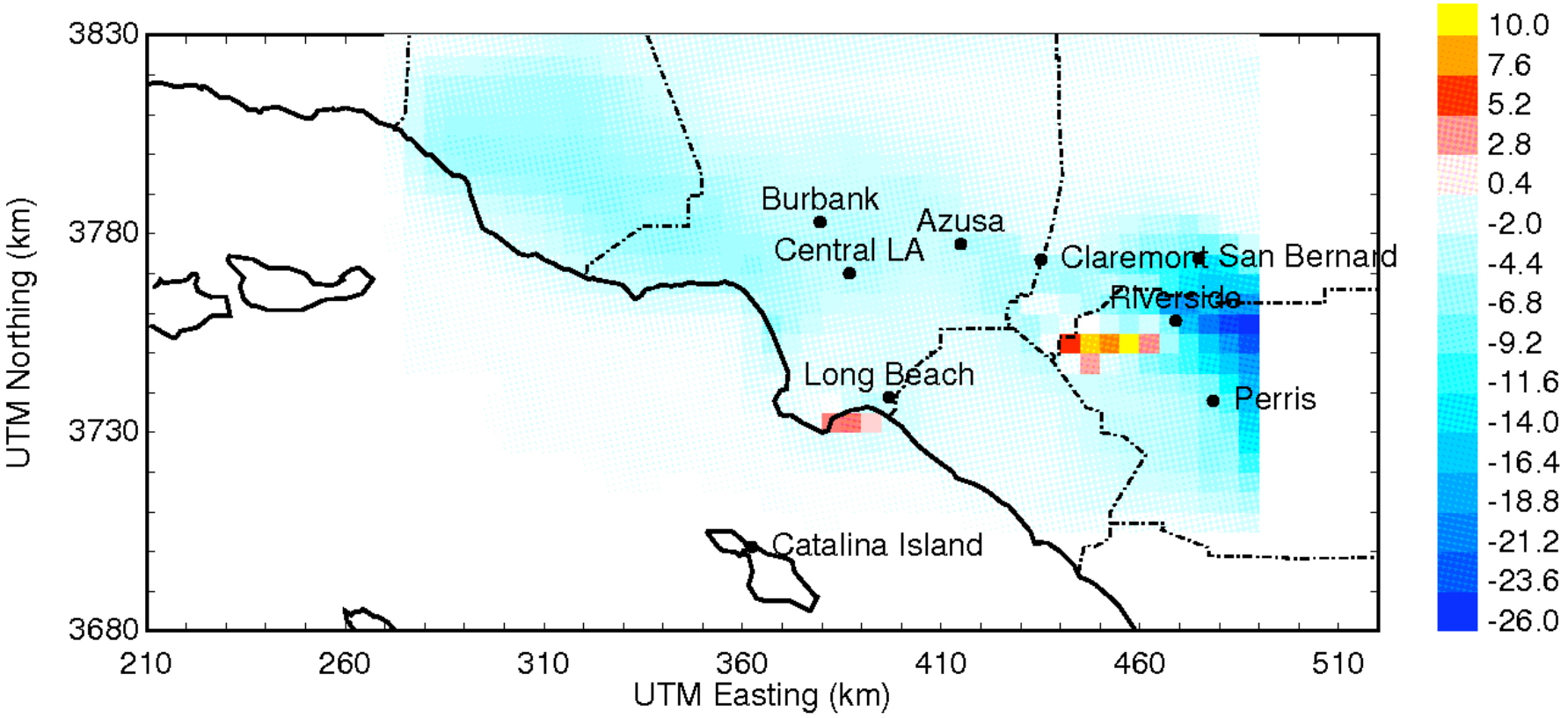
Background O3 concentrations have increased over the past 100 years.

Projections by IPCC estimate future concentrations at ~60ppb.

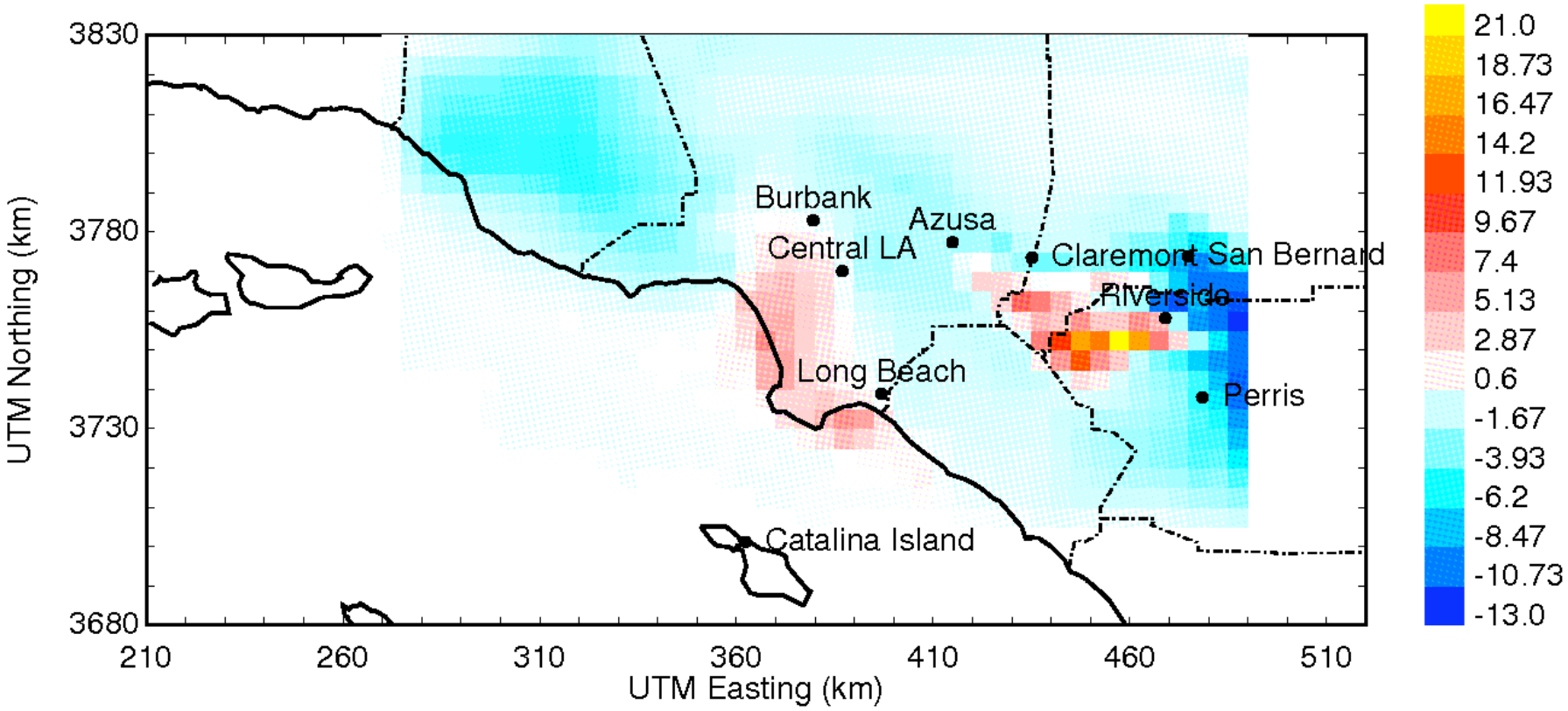


Source: R. Vingarzan, “A review of ozone background levels and trends”, Atmospheric Environment, 38: 3431-3442.

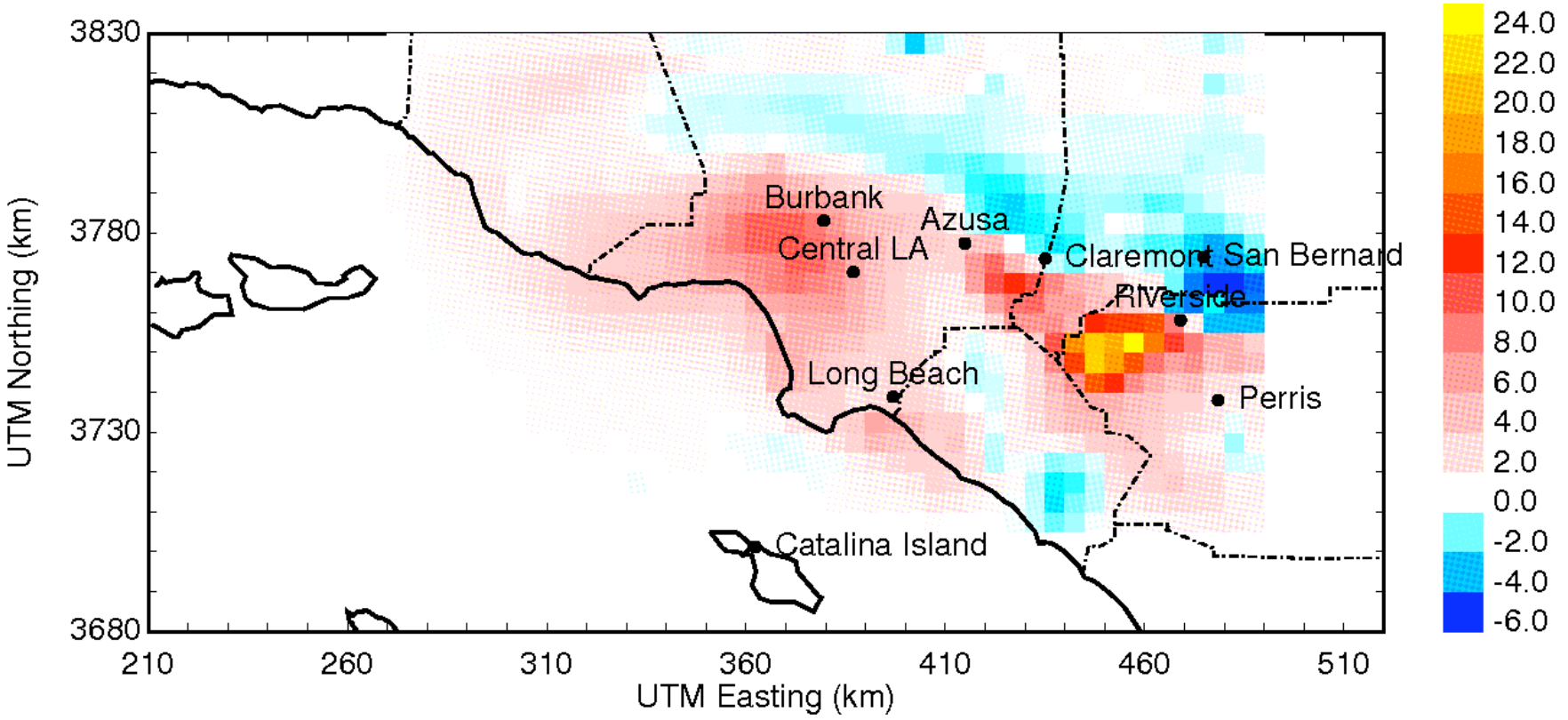
24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +5K With 60ppb Background O3



24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +5K With Constant RH and 60ppb Background O3



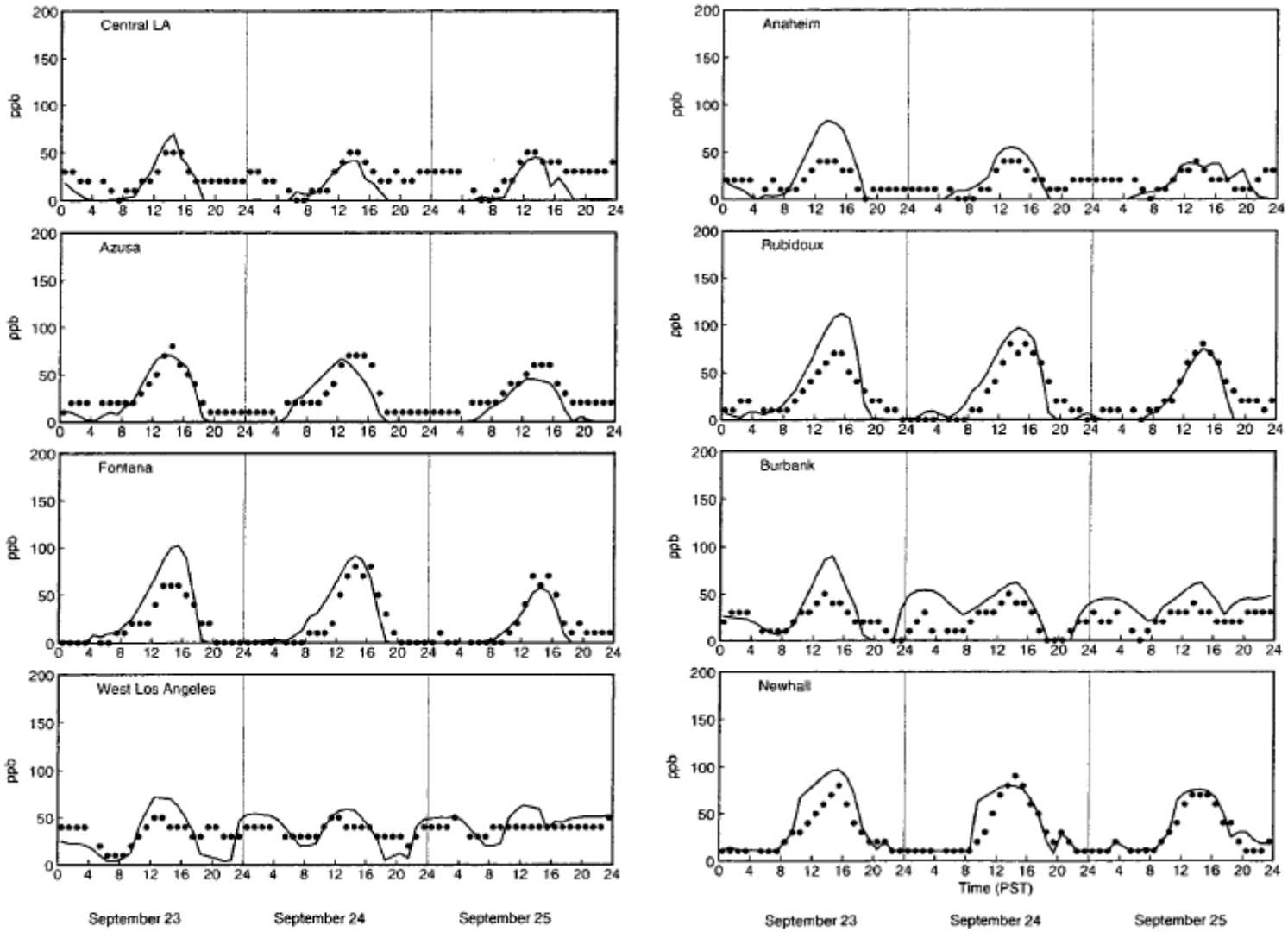
24hr-Average PM2.5 Concentration Difference ($\mu g\ m^{-3}$) Caused By +50% Mixing Depth and 60ppb Background O3



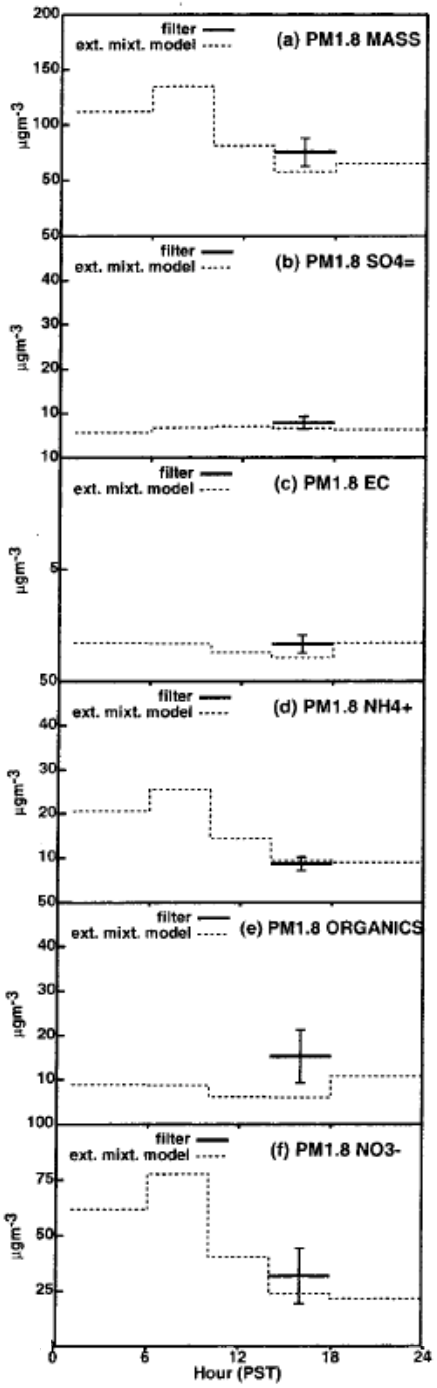
Episode # 2: SoCAB September 23-25, 1996

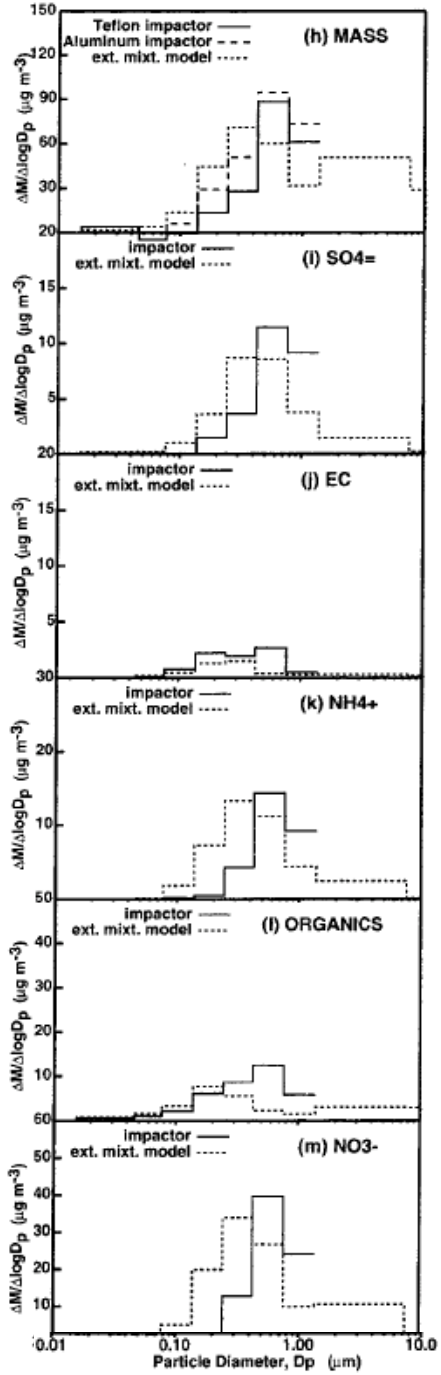
- Moderate daytime temperatures reaching 25^{o}C
- Elevated temperature inversion
- Surface winds light from the west during the day, stagnant at night

Predicted vs. Measured O3

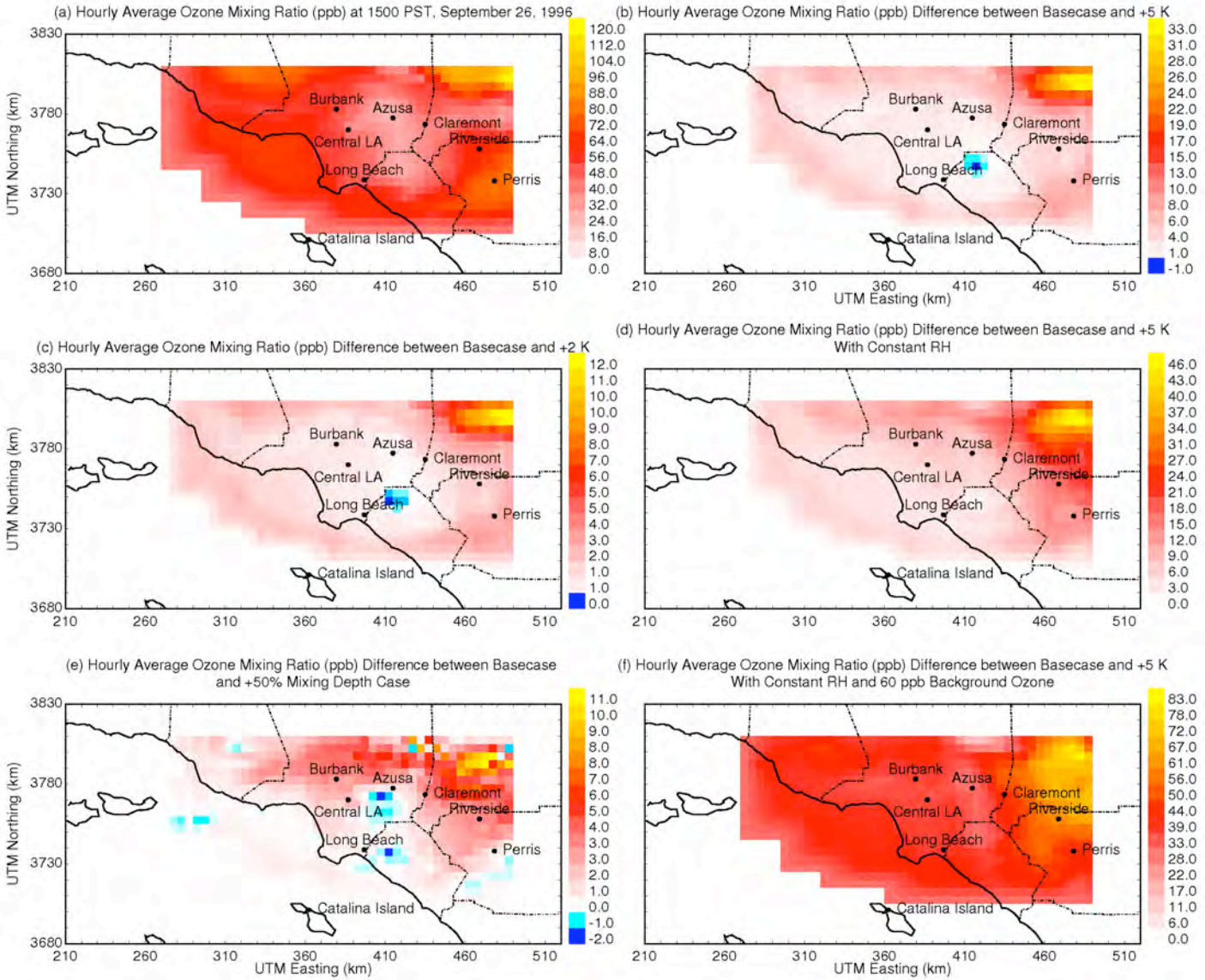


Comparison to Measurements for Particle Mass and Composition:

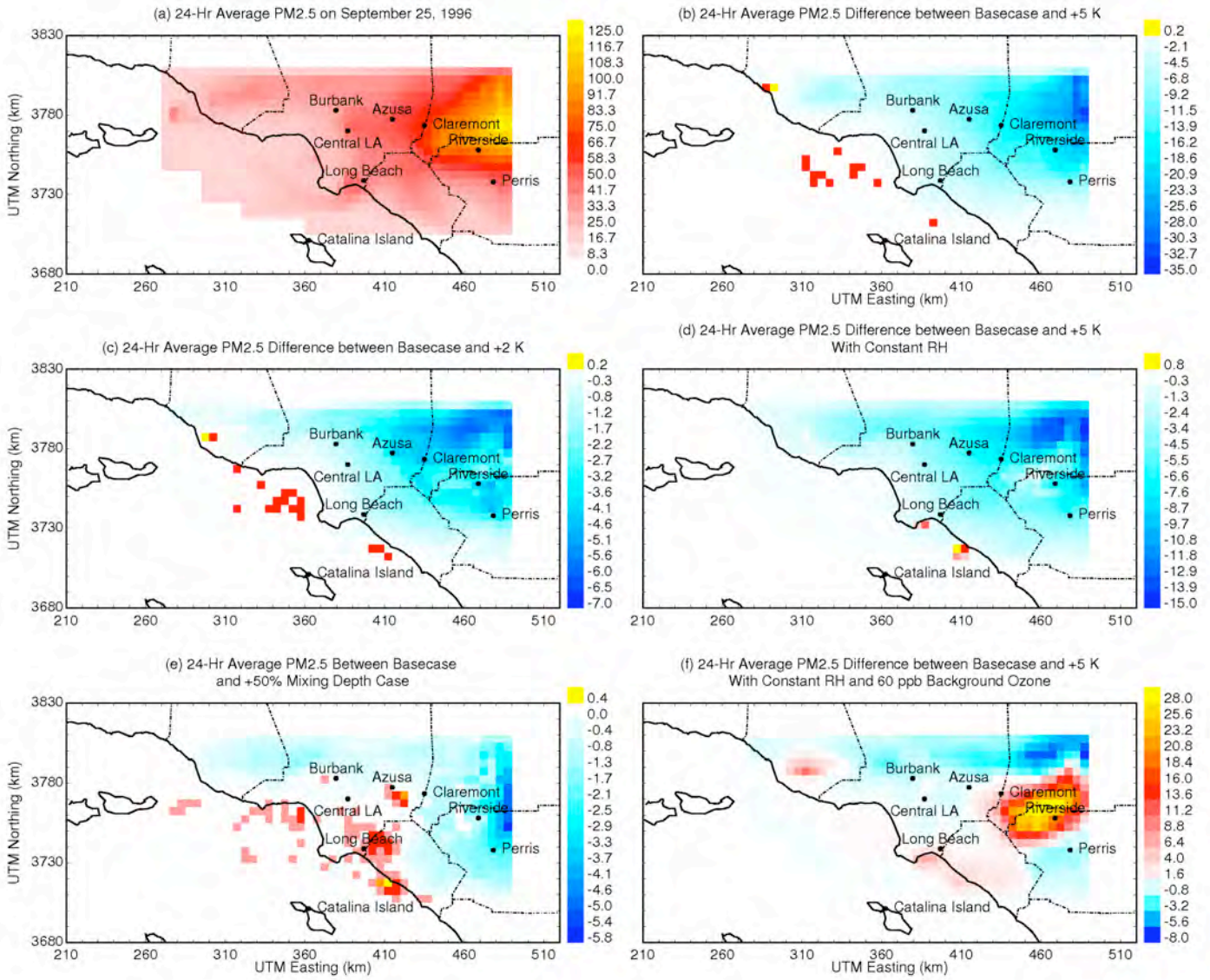




O3 Response to Temperature and Humidity: September 25, 1996



PM2.5 Response to Temperature and Humidity: September 25, 1996



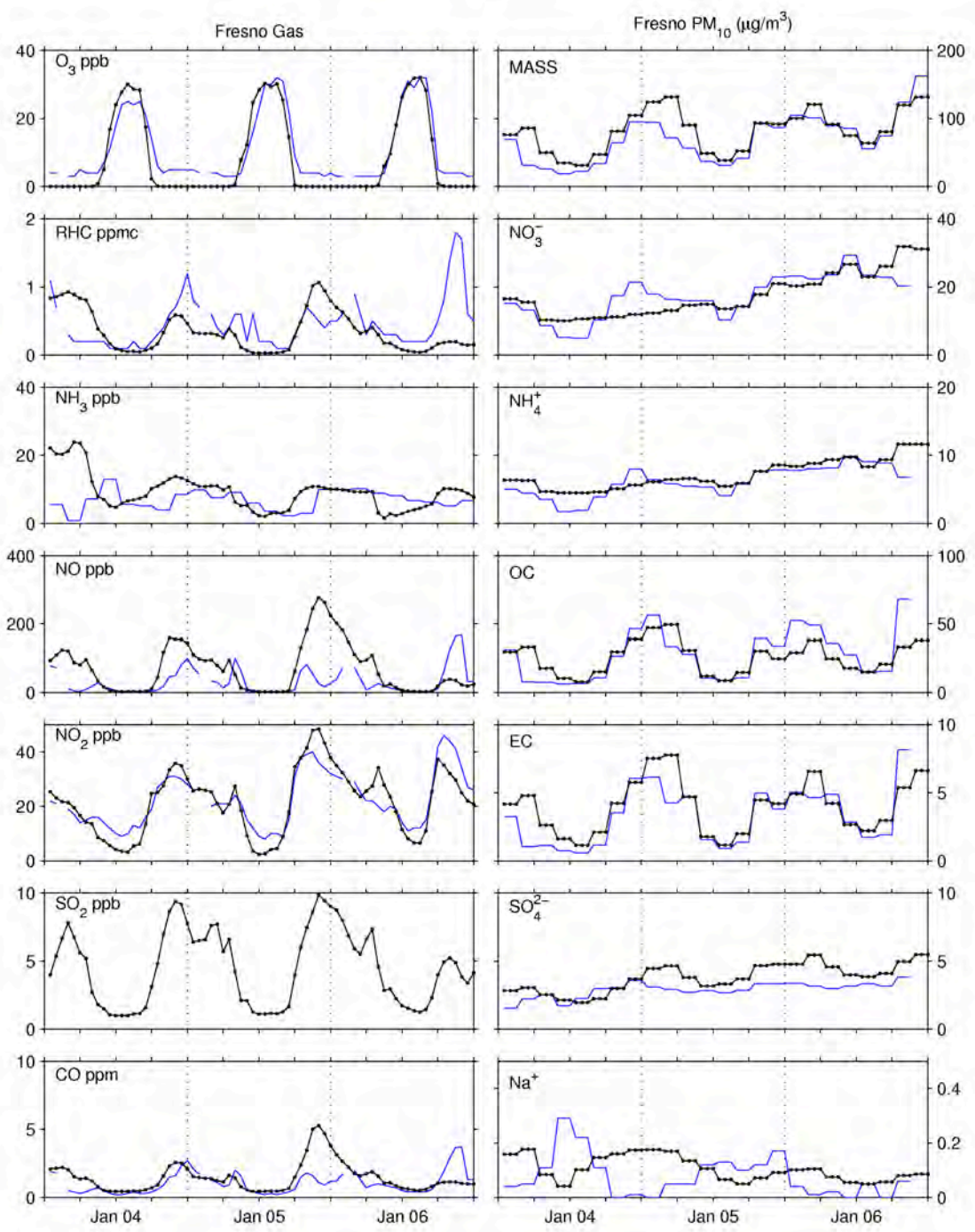
Episode # 3: SJV January 4-6, 1996

- Temperatures between 0-15^{o}C
- Strong elevated temperature inversion at 200-500m
- Surface inversion with depth of ~30m forms at night
- Light surface winds with variable direction

Fresno

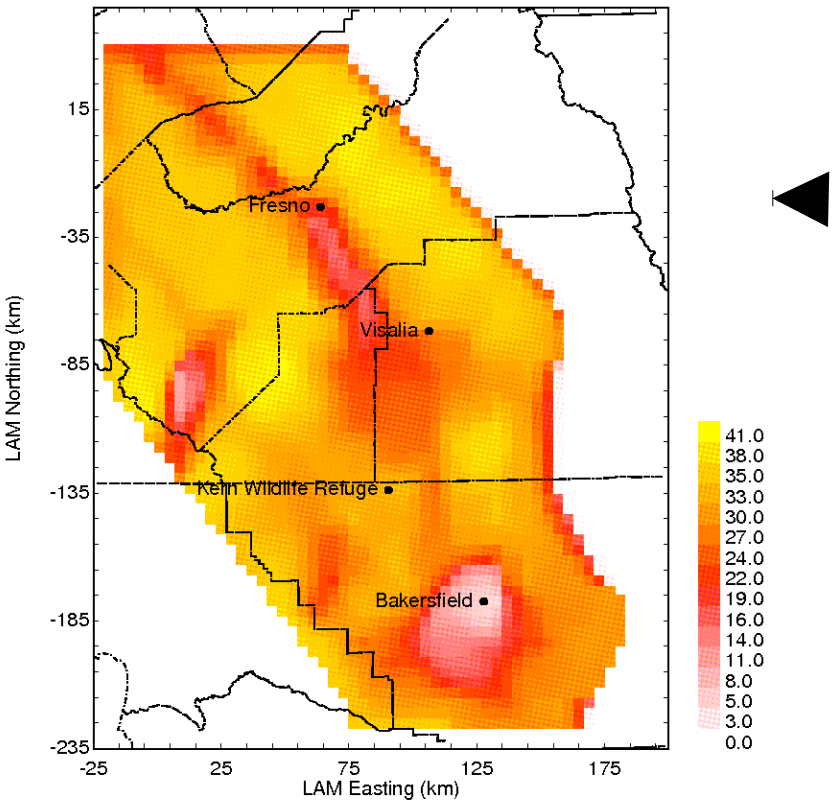
Modeled: black

Measured: blue

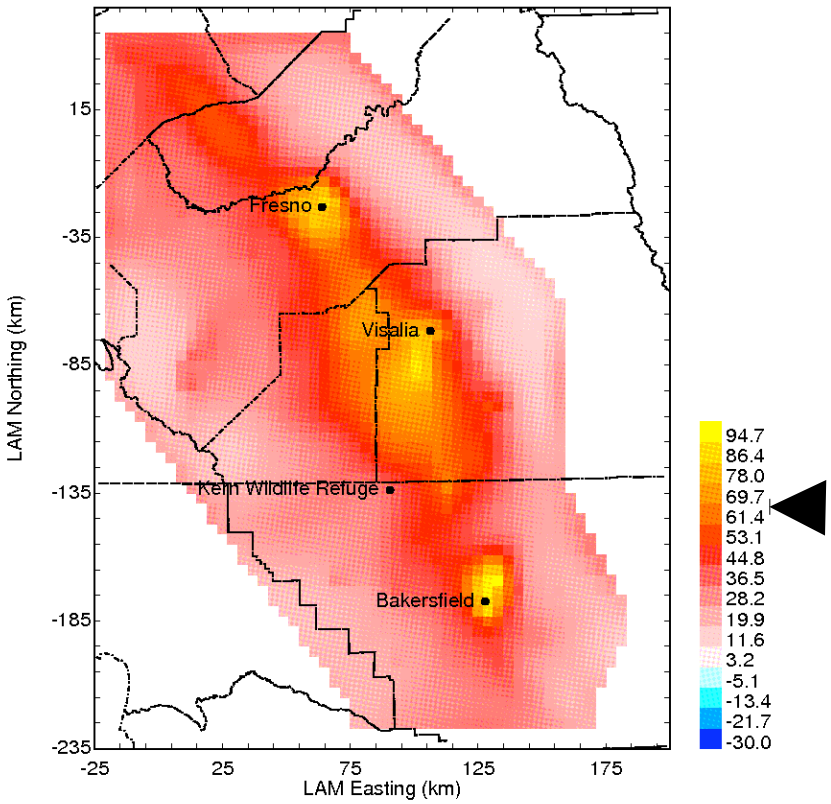


O3 and PM2.5 Concentrations

a Hourly Average Ozone Mixing Ratio (ppb) at 1500 PST, January 6, 1996

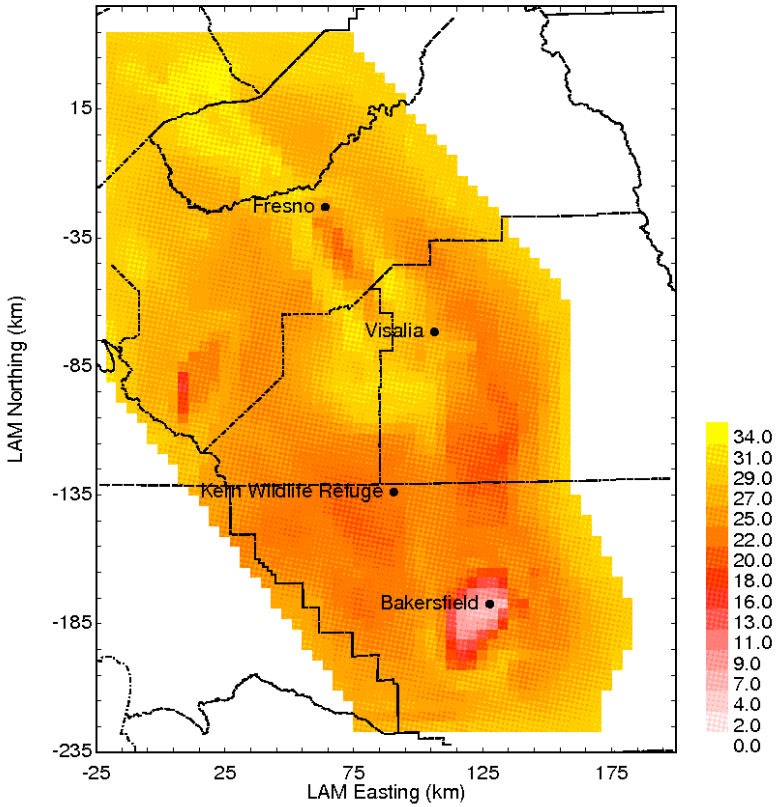


b 24-hour Average PM2.5 Concentration for Basecase on January 6, 1996

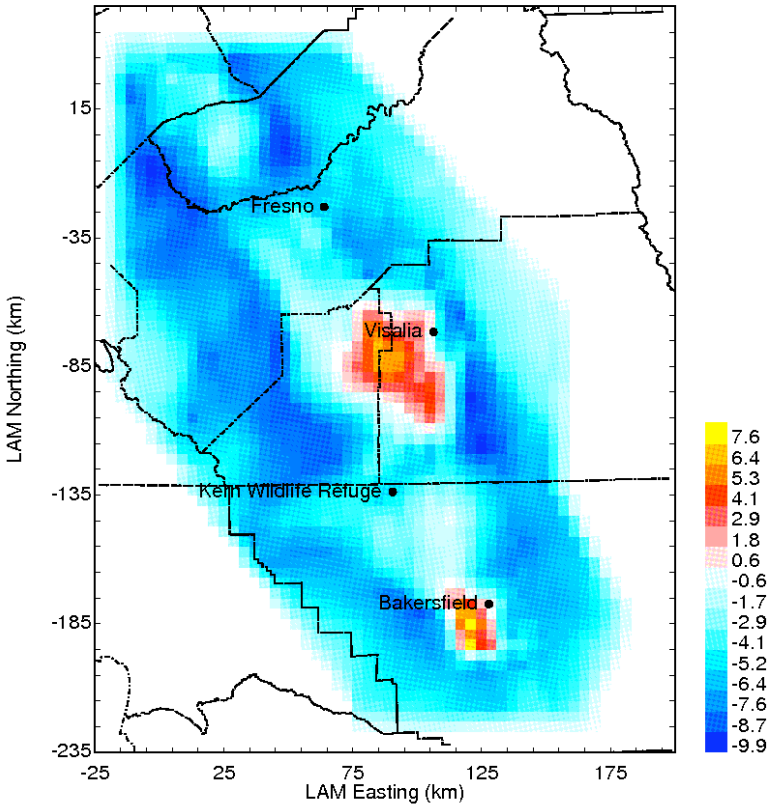


Concentration Difference Caused by +5K With 60ppb Background O3

e Hourly Average Ozone Mixing Ratio (ppb) Difference between Basecase and +5K Perturbation Case With 60ppb Background Ozone at 1500 PST, January 6, 1996

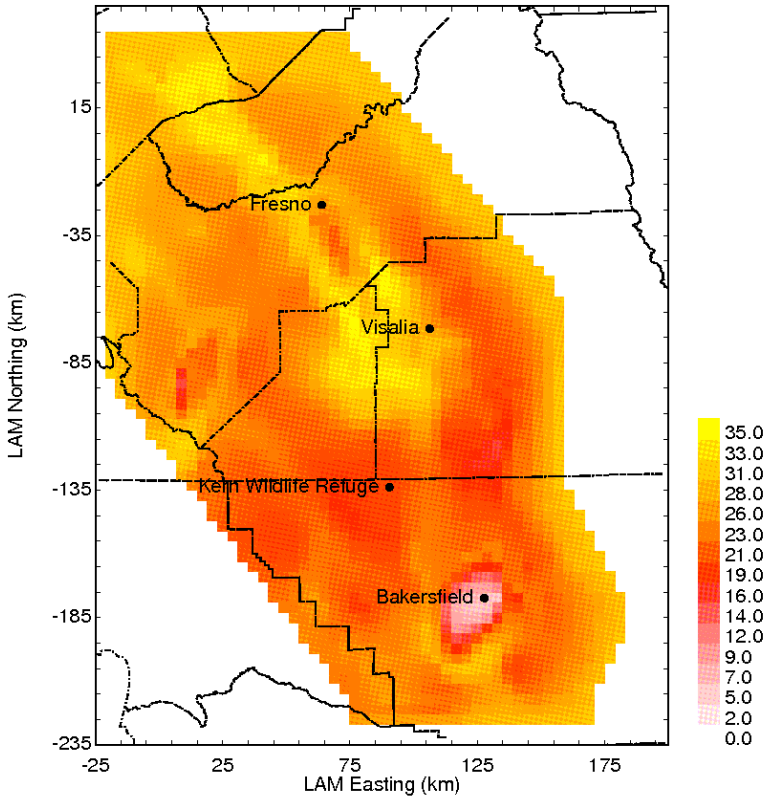


f 24-hour Average PM2.5 Concentration Difference between Basecase and +5K Perturbation Case With 60ppb Background Ozone

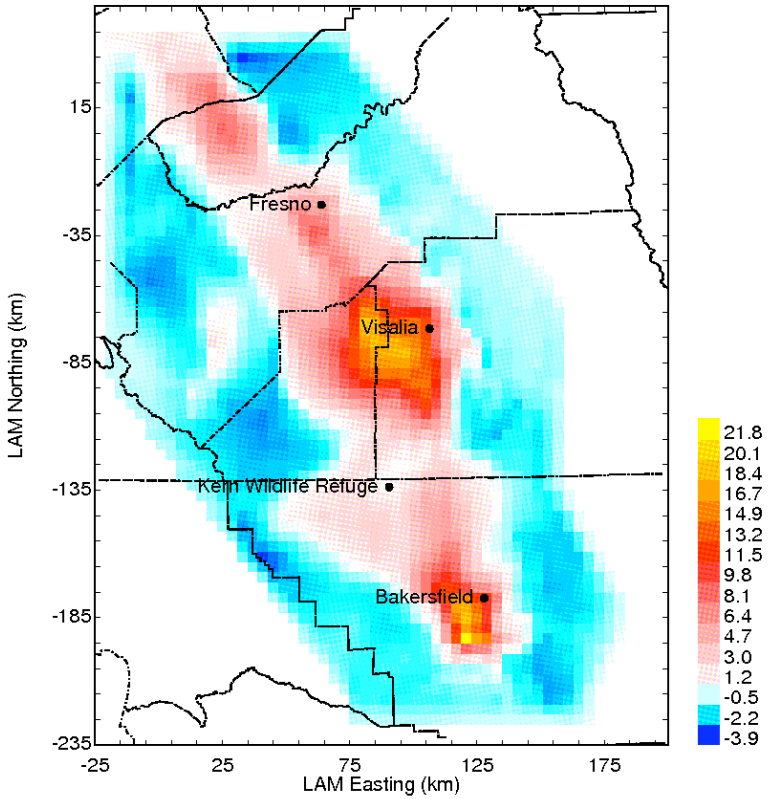


Concentration Difference Caused by +5K at Constant RH With 60 ppb Background O3

(e) Hourly Average Ozone Mixing Ratio (ppb) Difference between Basecase and +5K Perturbation With Constant RH and 60ppb Background Ozone at 1500 PST, January 6, 1996

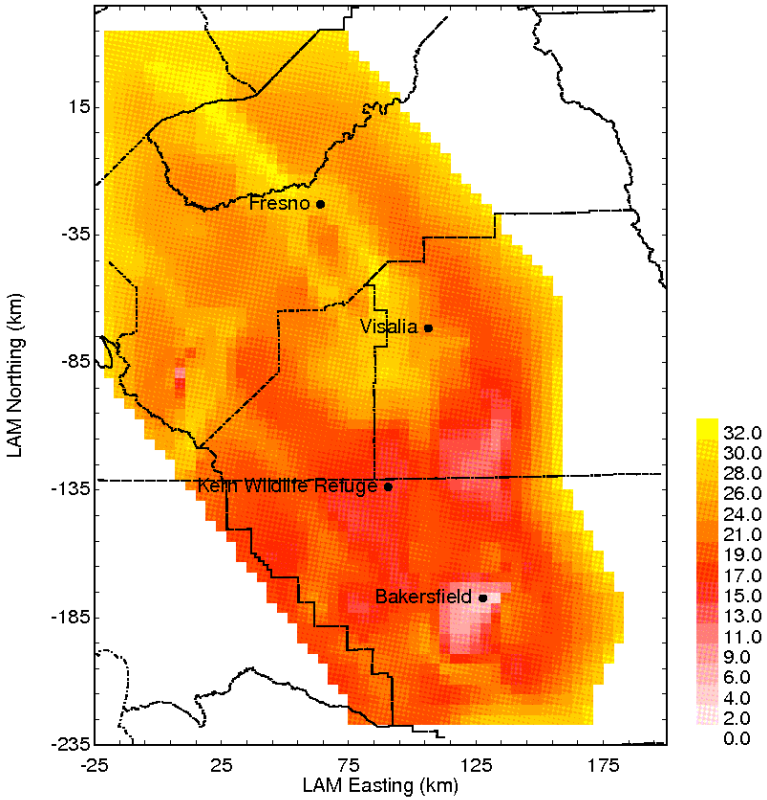


(f) 24-hour Average PM2.5 Concentration Difference between Basecase and +5K Perturbation With Constant RH and 60ppb Background Ozone

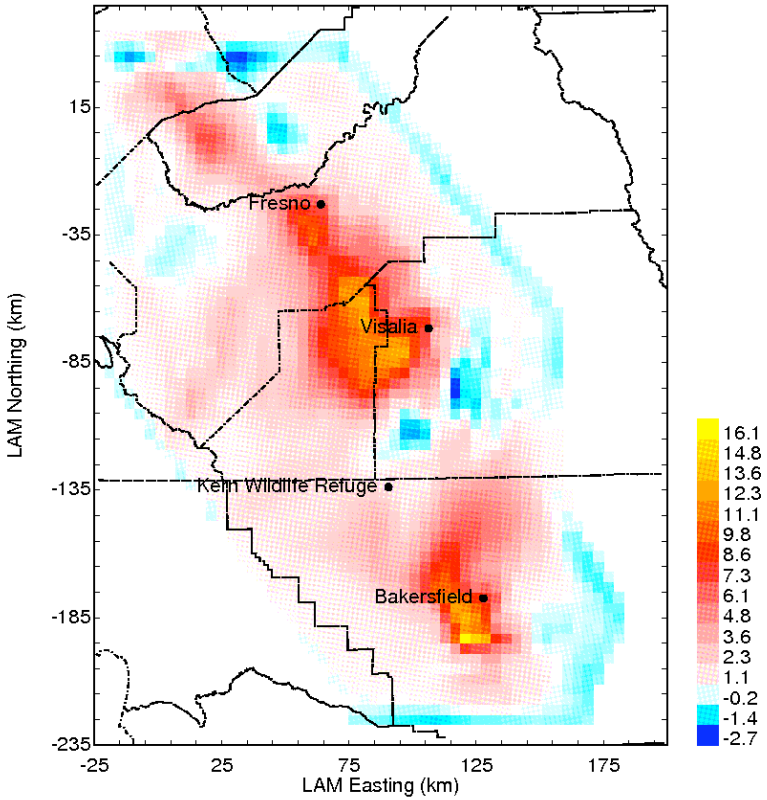


Concentration Difference Caused by +50% Increase in Mixing Depth with 60ppb Background O3

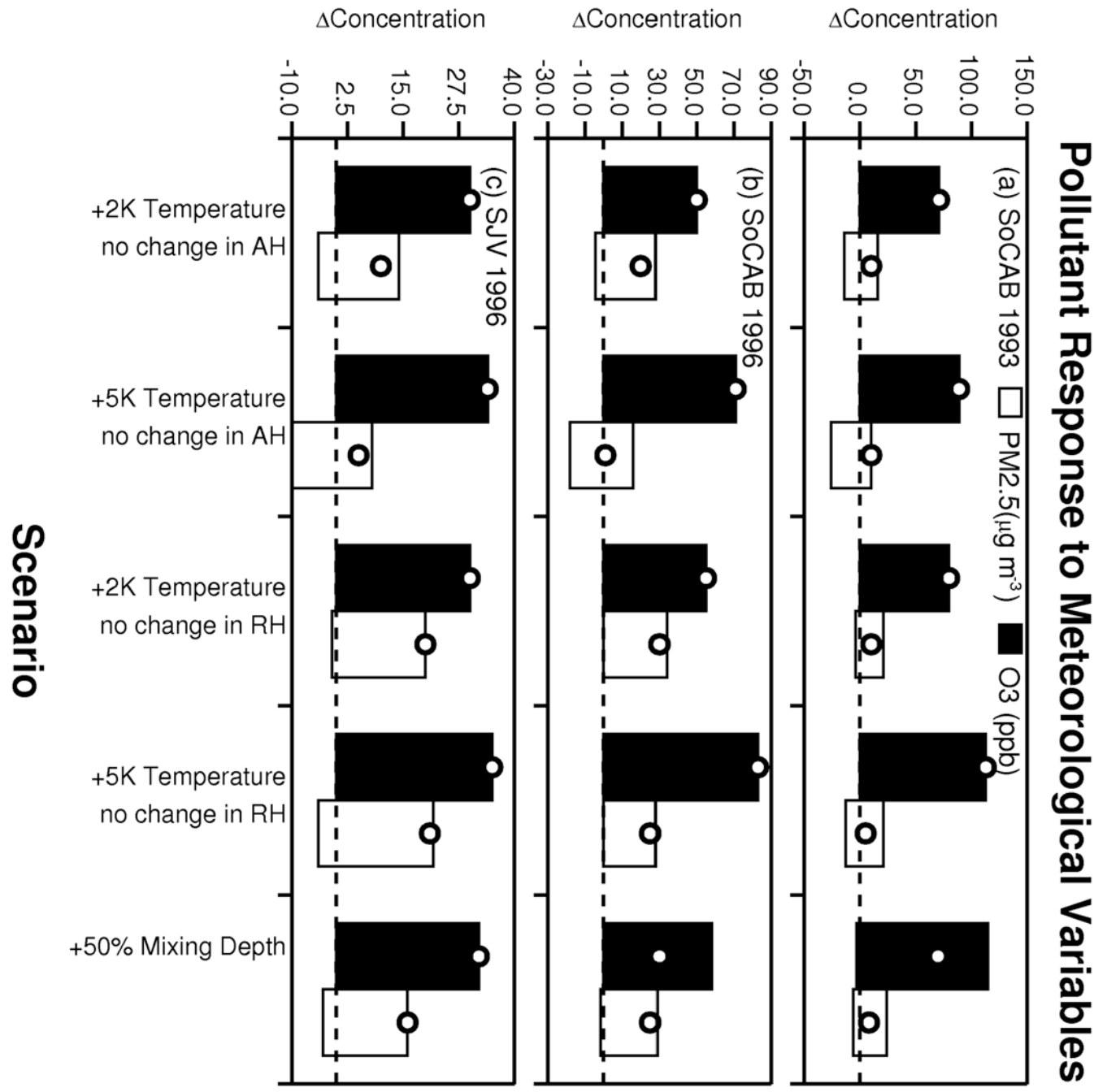
(c) Hourly Average Ozone Mixing Ratio (ppb) Different between Basecase and +50% Mixing Depth Perturbation 1500 PST, January 6, 1996



(d) 24-hour Average PM2.5 Concentration Difference between Basecase and +50% Mixing Depth Perturbation



Summary of Pollutant Response Across All Episodes (with 60ppb Background O3):



Conclusions

- Increased temperatures favor the formation of more ozone
- Increased temperature encourages evaporation of ammonium nitrate
- Increased background O3 produces higher nitrate concentrations
- Increased humidity favors the formation of ozone and ammonium nitrate
- Increased mixing depths provide more dilution of primary emissions
  - Lowers primary PM2.5
  - May increase ozone and secondary PM2.5

Conclusions

- Future stagnation events will be hotter
  - Likely produces more ozone
- Future stagnation events will have higher background O3 concentrations
  - Likely produces more ammonium nitrate

Acknowledgements

- California Air Resources Board Contract # 04-349
- Nehzat Motallebi (CARB)